ATLAS Status Report
Operations, Physics & Upgrades

P. Krieger, University of Toronto

(on behalf of ATLAS Canada)

IPP AGM, Halifax, June 15, 2018

ATLAS Canada Collaboration

Founded in 1992:	M. Lefebvre, UVic
Spokespersons:	R.S. Orr U of T 1994–2007
	R. McPherson, IPP/UVic 2007-2015

Alberta
Carleton
McGill
Montréal
SFU
Toronto
TRIUMF
UBC
Victoria
York

Current Management

Spokesperson, PI (2015 –):	P. Krieger, U of T
Deputy:	A. Warburton, McGill
Physics Coord:	A. Lister, UBC
Computing Coord:	D. Gingrich, Alberta

38 University/Lab faculty (≈ 35 FTE)
30 Postdocs, 80 GS (Fall 2017), ≈ 25 UG students/year
Plus engineers and technicians (some MRS funded)
Group includes 5 IPP Research Scientists (4 FTE)

ATLAS Canada Activities & HQP

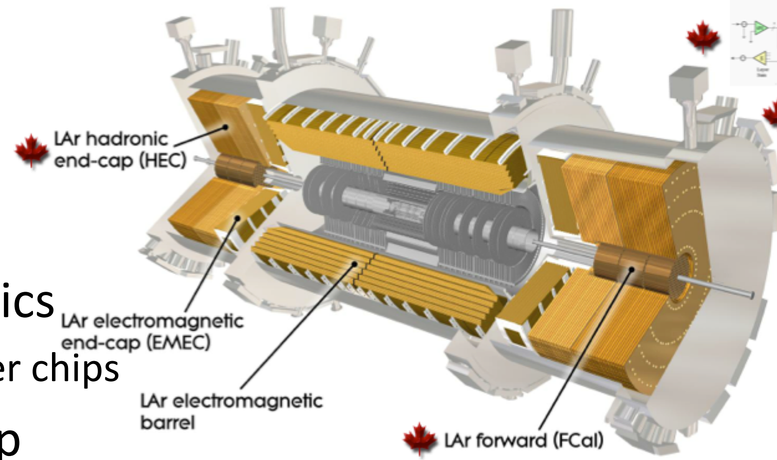
- **Canadians playing key roles in ATLAS and the ATLAS Physics program**
  - Physics: Physics Coordinator, Monte Carlo production coordinator
  - Performance: group convenors
  - Operations: subsystems Run Coordinators, detector experts, computing
  - Other: Executive Committee, Speakers Committee, Authorship Committee…
- **Well represented in Phase-1 and Phase-2 upgrade projects**
  - Both technical leadership and management roles
- **HQP training:**
  - 80 PhDs awarded on ATLAS (Sept 2017), 55 with collisions (Run 1, Run 2)
    - +10 since time of 2017 IPP AGM
  - Student awards (past grant cycle):
    - ATLAS Thesis award (1 of 4) 2015
    - Carleton Gold Medal & Governor General's award 2017
  - Close to 100 RAs have been trained within ATLAS Canada
    - ATLAS Outstanding achievement awards (3/20 in 2016):
      - Last set of awards: next set to be for full Run 2 period

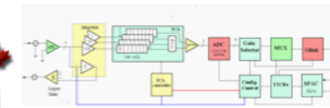
The Large Hadron Collider at CERN

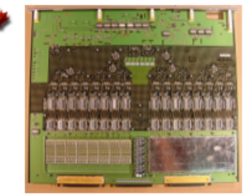
- **The world's highest-energy particle collider:**
  - Likely to remain at the energy-frontier for at least another two decades
  - Running at or above design luminosity since June 2016
- **Over 750 scientific ATLAS publications (published or submitted)**
- **Higgs discovery in 2012 $\rightarrow$ 2013 Nobel Prize to Higgs and Englert**
  - Investigations of Higgs properties still important and on-going
  - Results for new production / decay modes using Run-2 data
    - Including recent updates with up to 80 fb^{-1} of 13 TeV data
- **Run-2 operation (2015-2018) at 13 TeV**
  - Will increase to 14 TeV for Run-3
  - Maximum LHC energy is 14 TeV. After that, planned improvements are associated with an increase of the luminosity:
    - Accommodating such increases is the goal of the ATLAS upgrade program
- **Canadian group playing leading roles in a number of upgrade projects**
  - Funding from CFI: IF 2015 (Phase-1) and IF 2017 (Phase-2)
  - In each case following on from RTI support from NSERC during the R&D phase

Canadian hardware contributions to ATLAS

- Hadronic Endcap calorimeter
  - Two of four wheels
- Hadronic Forward calorimeter
  - All four modules
- Liquid argon front-end electronics
  - Switched capacitor array controller chips
- Liquid argon calorimeter endcap signal feed-throughs

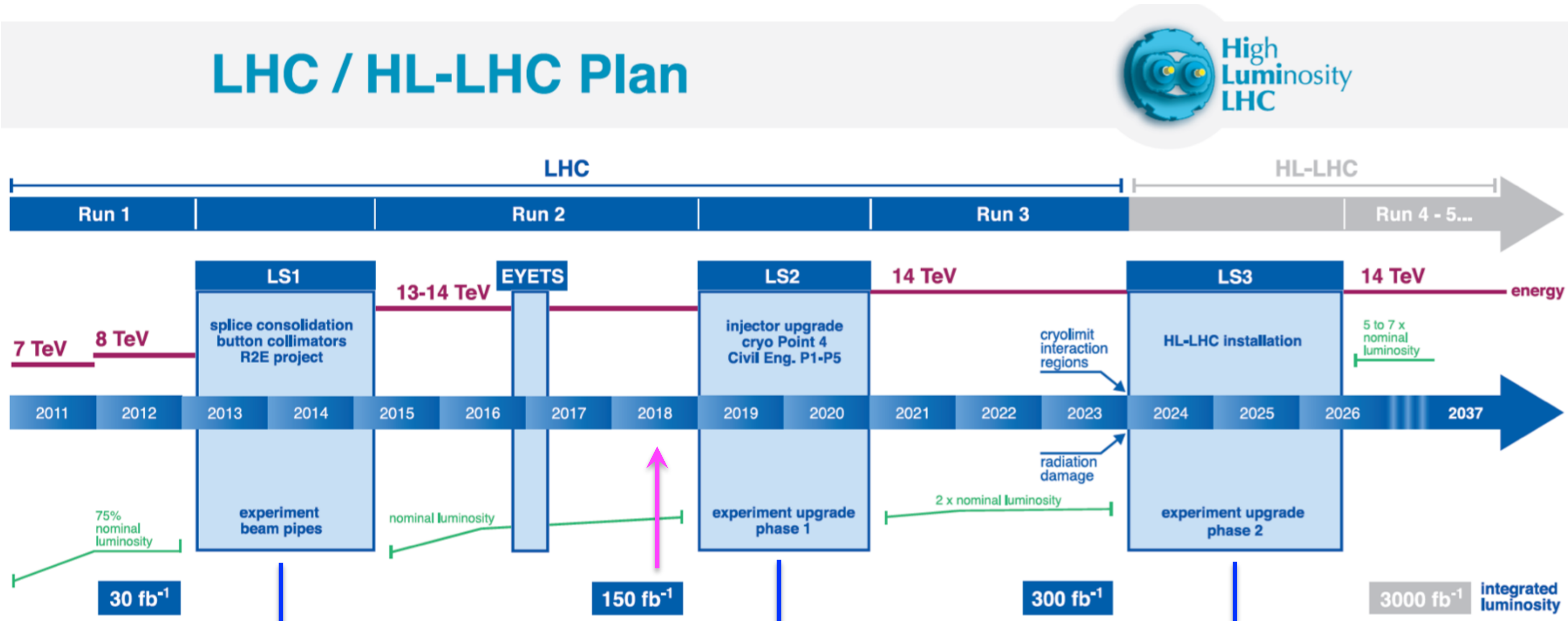






- ATLAS Tier-1 and Tier-2 Computing facilities
- High-level trigger (HLT) processors
- Diamond Beam Conditions Monitor (also used for luminosity)
- MediPix / TimePix for cavern background monitoring, luminosity
- LUCID luminosity monitor and upgrade in LS1 (2013-2015)
- Diamond Beam Monitor (telescope) installed in LS1 (2013-2015)
- Inner Detector (TRT) readout
- ATLAS Forward Protons (AFP) − installation completed in 2016/17 shutdown

LHC/HL-LHC Schedule & ATLAS upgrade planning



- New Pixel insertable b-layer (IBL): DBM
- Consolidation of LAr calorimeter LVPS
- LUCID upgrade
- Forward protons (AFP)

Completed

- sTGC for Muon New Small Wheel
- Liquid Argon Calorimeter electronics

Under construction

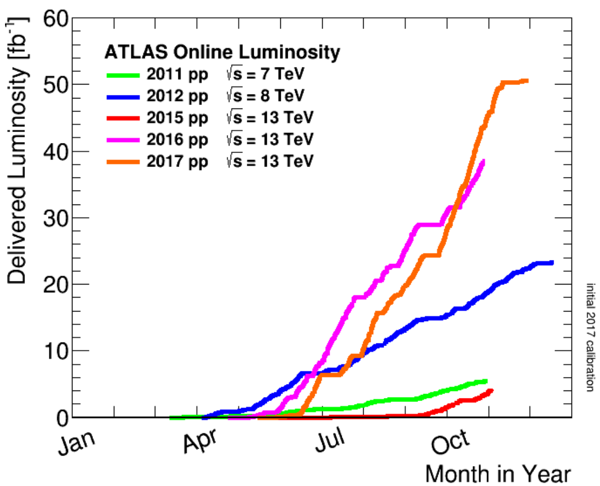
- New ATLAS Inner Tracker (ITk)
- Liquid Argon Calorimeter readout electronics

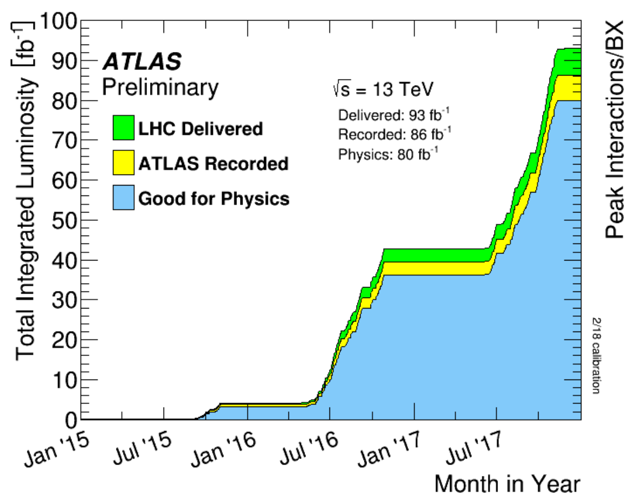
In progress

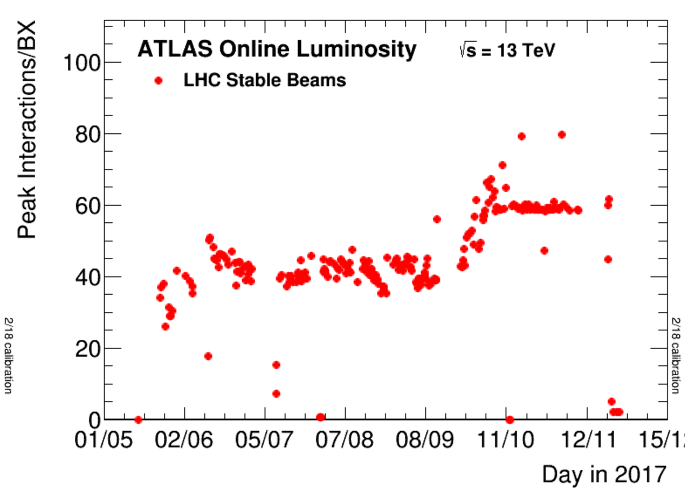
Main ATLAS Canada shutdown / upgrade activities

LHC/ATLAS Run-2 Operations (2017)

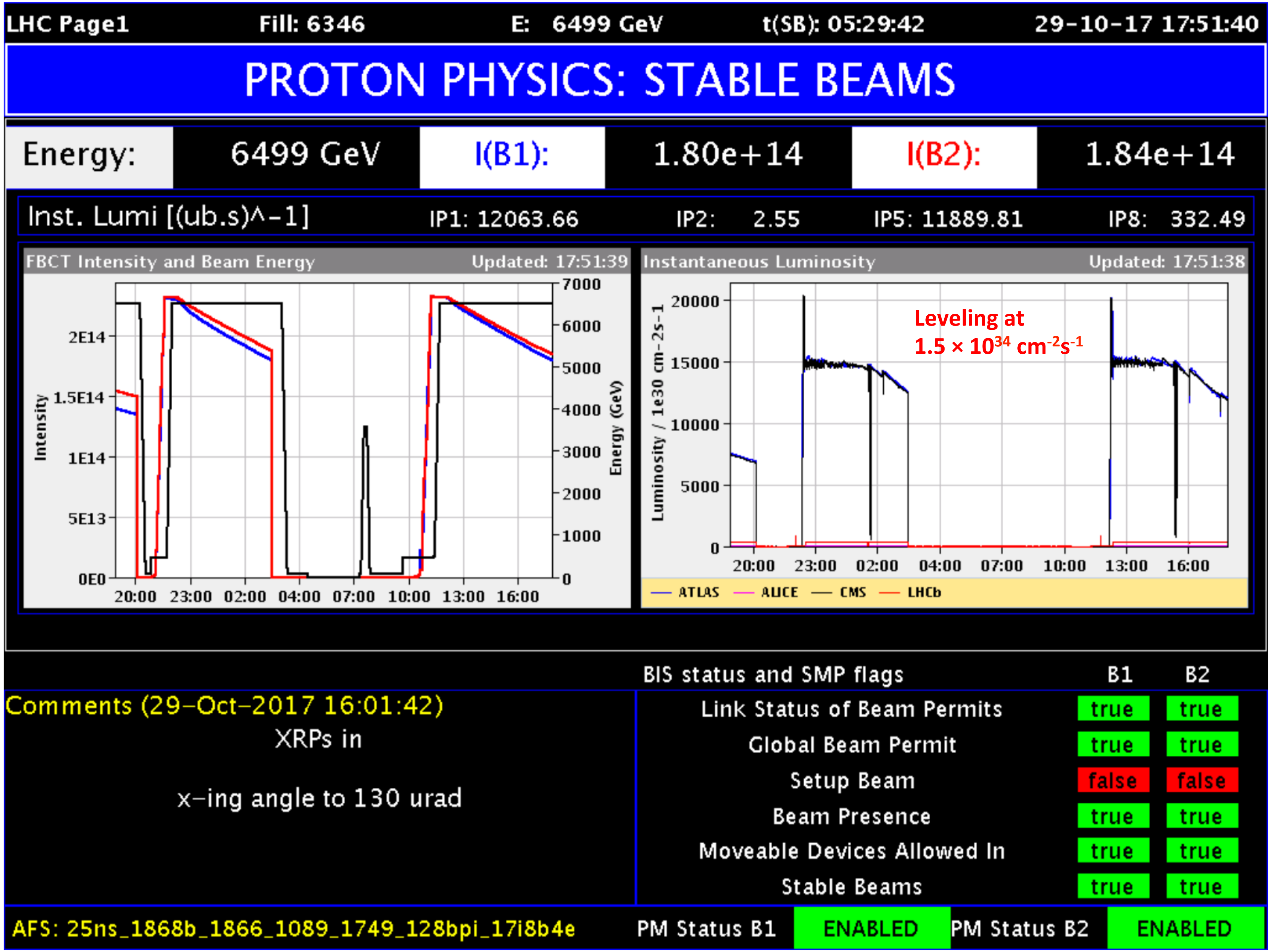
- **Last IPP AGM coincided with the start of 2017 operations. That run year was very successful despite some challenges with the machine:**
  - Beam losses in cell 16L2 (LHC sector 1-2)
    - Mitigation with special beam configuration “8b4e” (8 filled bunches then 4 empty)
    - Results in large increase in pileup; introduction of leveling at <μ> ≈ 60
  - Excellent machine availability: 49% of time in Stable beams (average for year)
  - Later than usual startup – extended technical stop for CMS pixel work







Run-2 dataset for 2015 – 2017 80 fb^{-1} good for physics


LHC Page1
Fill: 6346
E: 6499 GeV
t(SB): 05:29:42
29-10-17 17:51:40
PROTON PHYSICS: STABLE BEAMS
Energy: 6499 GeV
I(B1): 1.80e+14
I(B2): 1.84e+14
Inst. Lumi [(ub.s)^-1]
IP1: 12063.66
IP2: 2.55
IP5: 11889.81
IP8: 332.49
FBCT Intensity and Beam Energy
Updated: 17:51:39
Intensity
Energy (GeV)
0E0
5E13
1E14
1.5E14
2E14
0
1000
2000
3000
4000
5000
6000
7000
20:00
23:00
02:00
04:00
07:00
10:00
13:00
16:00
Instantaneous Luminosity
Updated: 17:51:38
Luminosity / 1e30 cm-2s-1
0
5000
10000
15000
20000
Leveling at
1.5 × 10^34 cm^-2s^-1
ATLAS
ALICE
CMS
LHCb
BIS status and SMP flags
B1
B2
Link Status of Beam Permits true true
Global Beam Permit true true
Setup Beam false false
Beam Presence true true
Moveable Devices Allowed In true true
Stable Beams true true
Comments (29-Oct-2017 16:01:42)
XRPs in
x-ing angle to 130 urad
AFS: 25ns_1868b_1866_1089_1749_128bpi_17i8b4e
PM Status B1 ENABLED
PM Status B2 ENABLED

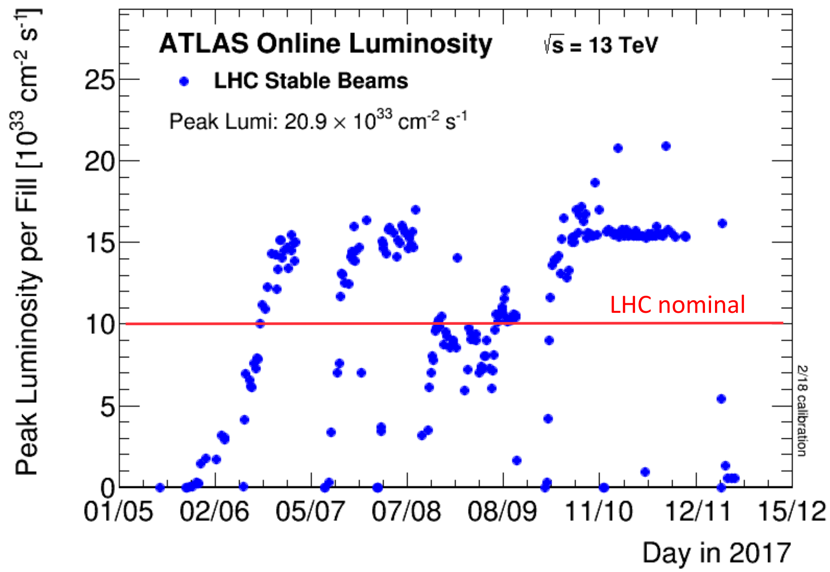
LHC/ATLAS 2017 Operations

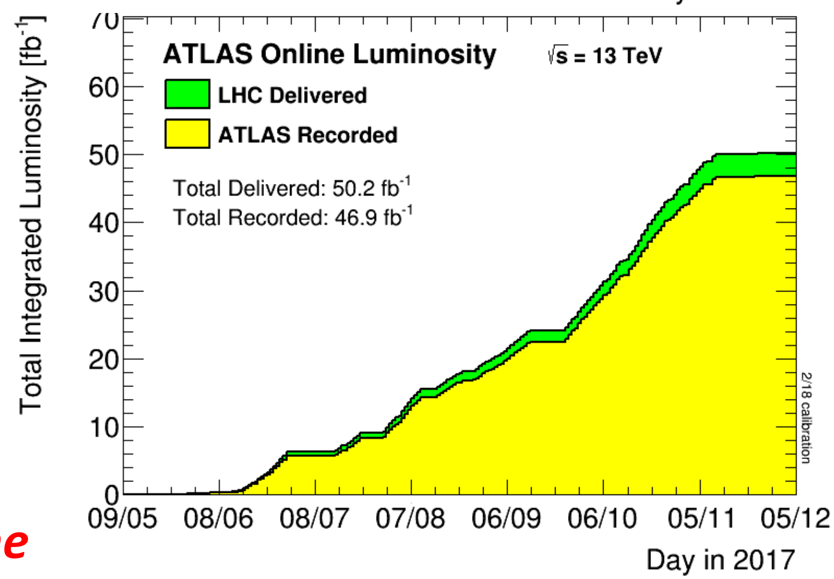
ATLAS Run-2 Detector Status (from July 2017)

Subdetector	Number of Channels	Approximate Operational Fraction
Pixels	92 M	97.8%
SCT Silicon Strips	6.3 M	98.7%
TRT Transition Radiation Tracker	350 k	97.2%
LAr EM Calorimeter	170 k	100 %
Tile Calorimeter	5200	99.2%
Hadronic End-Cap LAr Calorimeter	5600	99.5%
Forward LAr Calorimeter	3500	99.7%
LVL1 Calo Trigger	7160	99.9%
LVL1 Muon RPC Trigger	383 k	99.8%
LVL1 Muon TGC Trigger	320 k	99.9%
MDT Muon Drift Tubes	357 k	99.7%
CSC Cathode Strip Chambers	31 k	95.3%
RPC Barrel Muon Chambers	383 k	94.4%
TGC End-Cap Muon Chambers	320 k	99.5%
ALFA	10 k	99.9%
AFP	430 k	93.8%

ATLAS pp 25ns run: June 5-November 10 2017

Inner Tracker			Calorimeters		Muon Spectrometer				Magnets	
Pixel	SCT	TRT	LAr	Tile	MDT	RPC	CSC	TGC	Solenoid	Toroid
100	99.9	99.3	99.5	99.4	99.9	97.8	99.9	100	100	99.2
Good for physics: 93.6% (43.8 fb^{-1})										

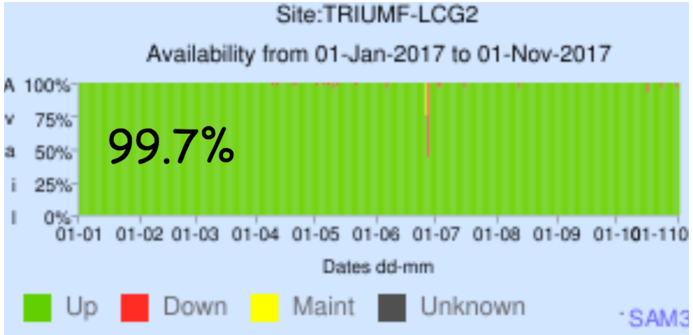




Overall excellent performance in 2017 of the LHC machine, the ATLAS detector, and ATLAS computing facilities (WLGC)

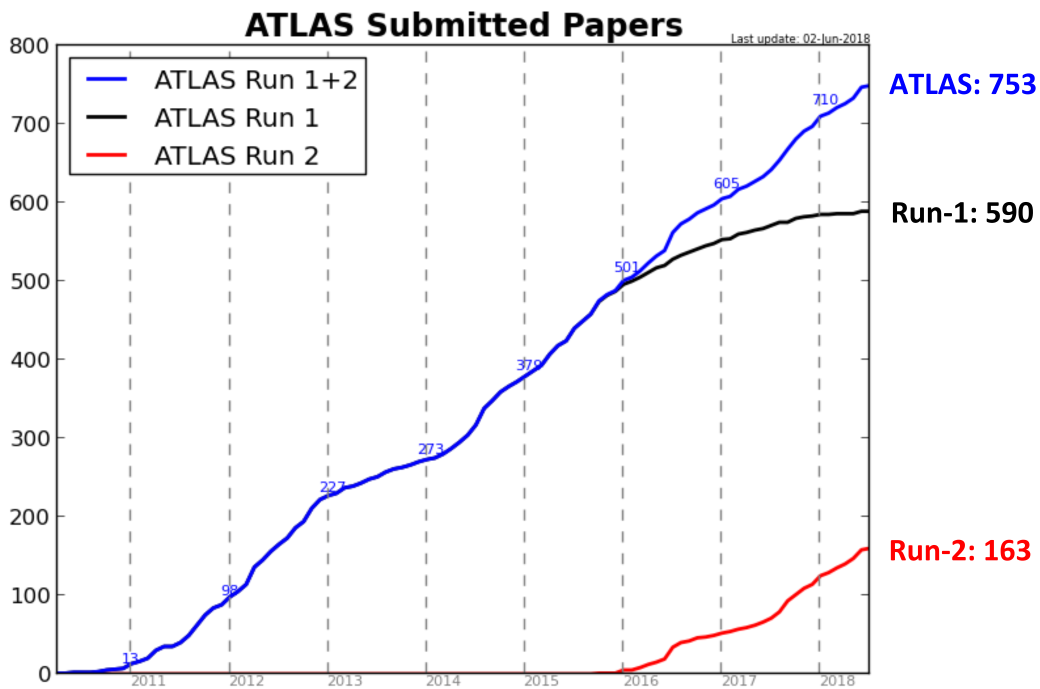
Operations: ATLAS Canada Computing

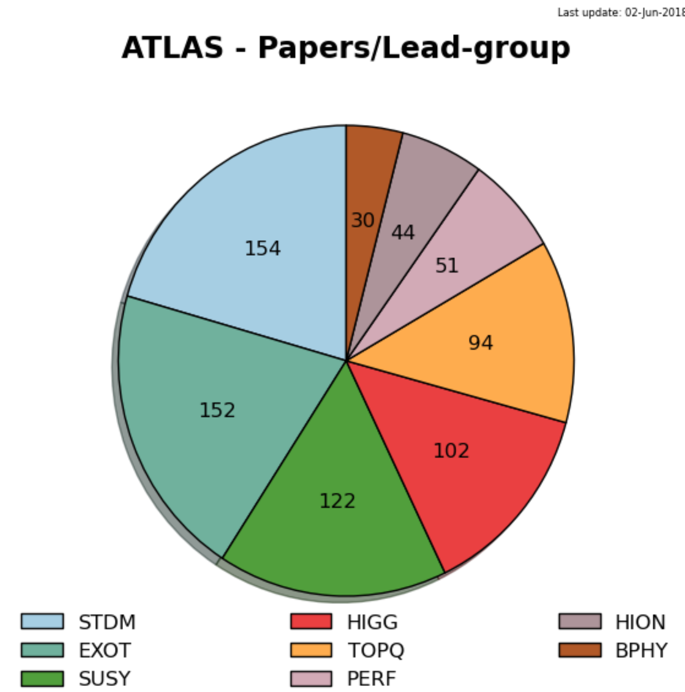
- **Computing resources are a critical part of ATLAS**
  - Challenging during Run-2 due to higher than expected pileup
- **Canada hosts 1 of the 10 ATLAS Tier-1s**
  - Typically one of the highest reliability Tier-1s
  - Currently being relocated from TRIUMF to SFU
  - Hardware funding secured through 2020, via CFI IF 2017 competition (matching from BCKDF)



- **We also provide 5% of ATLAS Tier-2 resources, via Compute Canada**
  - Compute Canada currently performing a site consolidation
  - Some issues for ATLAS Canada due to new sites not yet being fully commissioned
- **Necessary resources do not diminish during upcoming long shutdown**
- **ATLAS continues to rely on resources beyond those "pledged" to the WLCG, in the form of opportunistic access to HPC and cloud resources**
  - ATLAS-Canada group members play a leading role in ATLAS cloud computing effort
- **Canadians also involved in development of ATLAS core computing:**
  - People funded via CyberInfrastructure program: one person based at CERN
  - Also an important part of our HQP training progam

ATLAS Physics Results



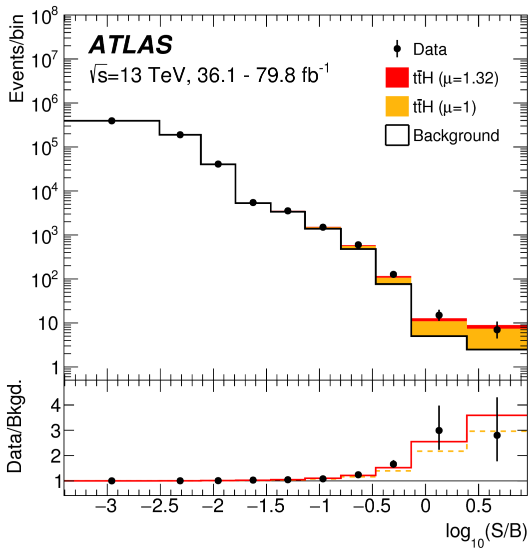


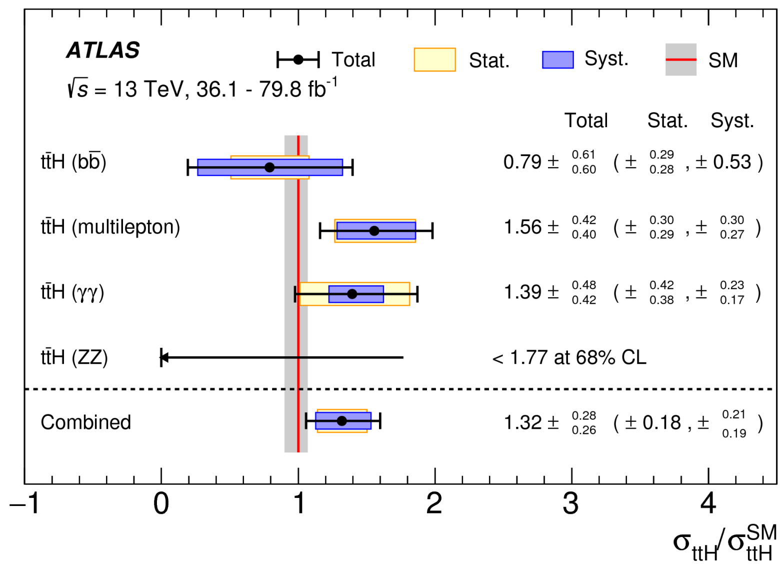
- **Run-1 papers +13 since last years AGM talk**
- **Run-2 papers +101 since last years AGM talk**
  - Mainly 2015 + 2016 (continuing to produce these publications): 36 fb^{-1}
  - Publication strategy is to focus next on papers based on the full Run-2 dataset
    - Plan for limited number of new / updated results including 2017 data
    - 7 such new results shown last week at LHCP 2018 http://lhcp2018.bo.infn.it/
    - Includes 6.3σ observation of $t\bar{t}H$ production

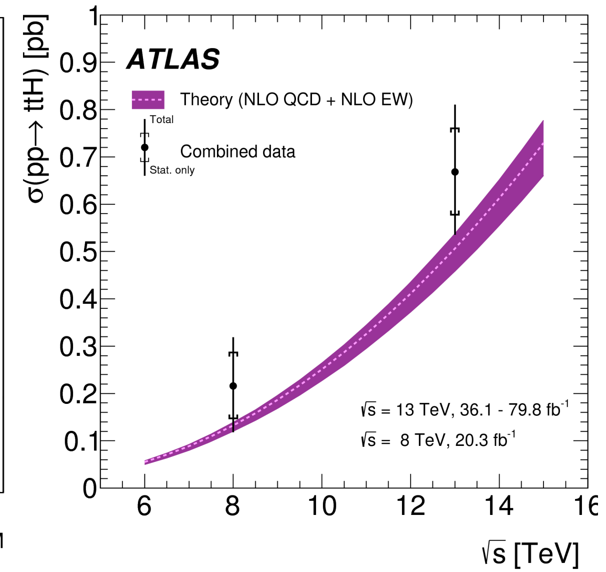
Higgs Boson Studies with 80 fb^{-1} ($t\bar{t}H$)

[1806.00425]

- **Observation of $t\bar{t}H$ production: Higgs final states:** $b\bar{b}, WW^*, \tau^+\tau^-, \gamma\gamma, ZZ^*$







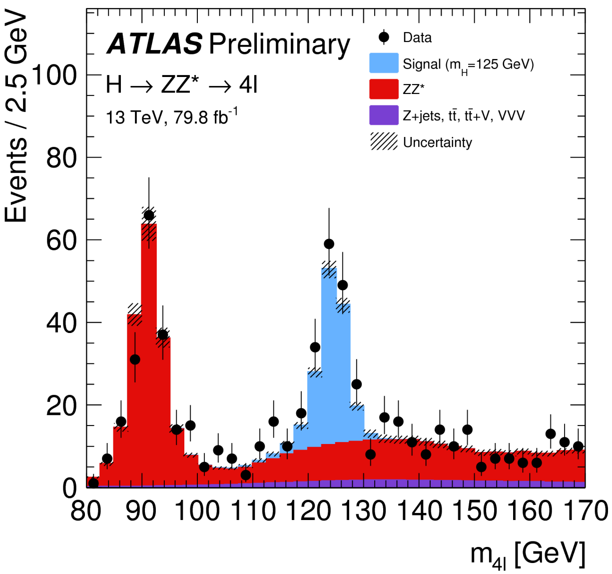
- **5.8σ with 13 TeV data (4.9σ expected)**
- **Combination with Run-1 result → 6.3σ (5.1σ expected)**
  - Announced simultaneously with 5.2σ result from CMS [CMS-HIG-17-035]
  - Significant Canadian leadership and involvement here:
    - Multiple Higgs final states
    - Both Run-1 and Run-2 analyses

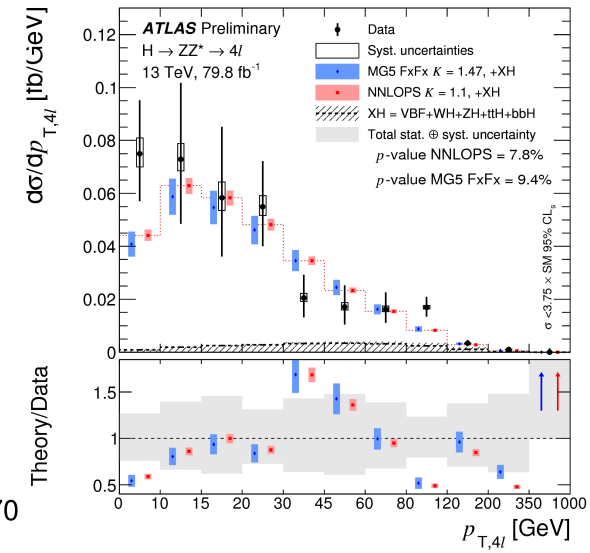
Measured cross sections in agreement with SM predictions

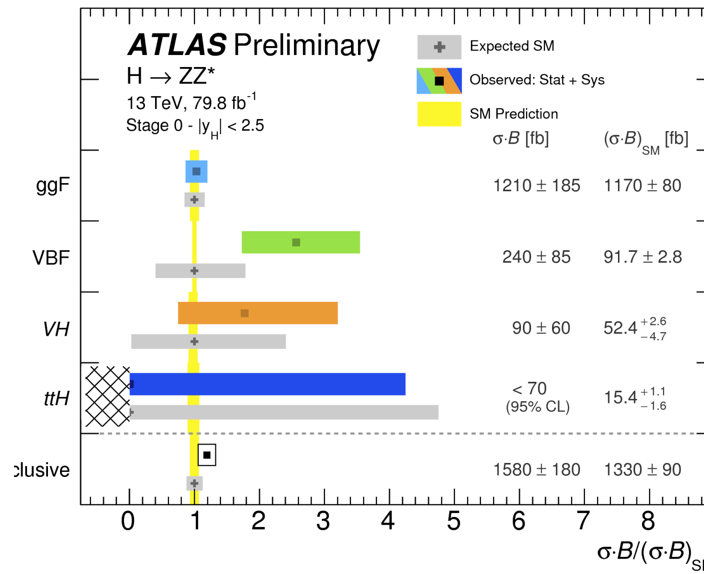
Higgs Boson Studies with 80 fb^{-1} ($H \to ZZ^* \to 4\ell$)

- **Updated analysis of Higgs $\to ZZ^* \to$ 4 lepton production:**
  - Inclusive, differential and production-mode cross-sections

ATLAS-CONF-2018-018







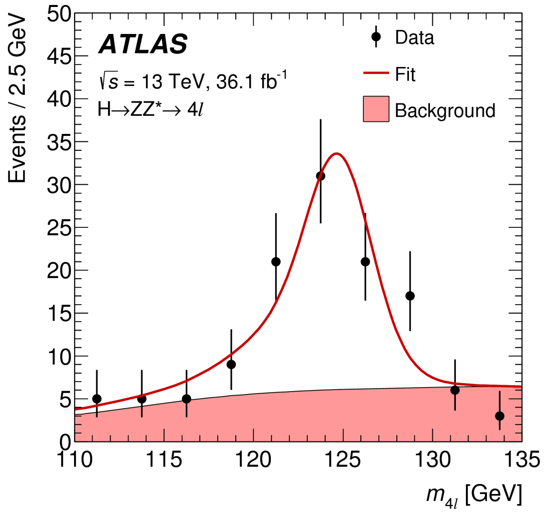
- **Measured cross-sections consistent with SM**

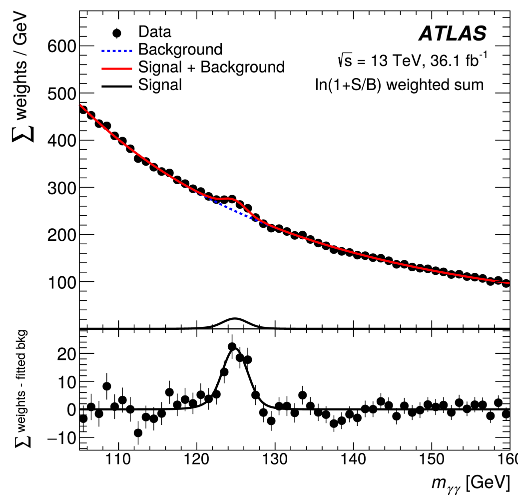
Complements / updates recently published ATLAS results on total and differential cross-sections from combined analysis of $\gamma\gamma, ZZ^* \to 4\ell$ final states, based on 36 fb^{-1} (2015+2016 data)

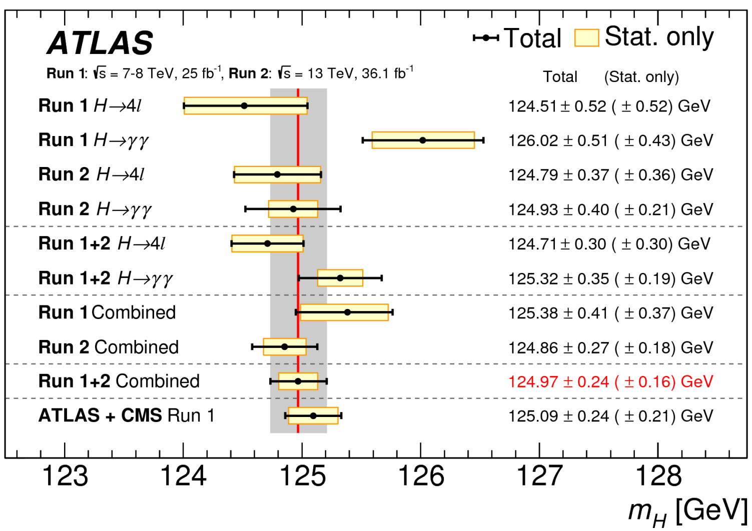
Higgs Mass and Cross-section using 36 fb^{-1}

Recently published Higgs mass and (combined) total and differential cross-section measurements based on 2015+16 data, in $\gamma\gamma, ZZ^* \rightarrow 4\ell$ final states

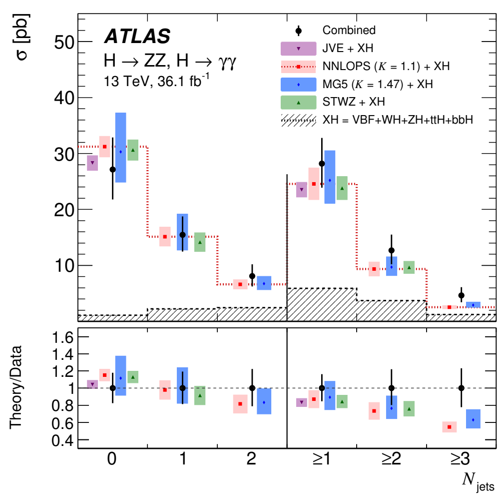
1806.00242

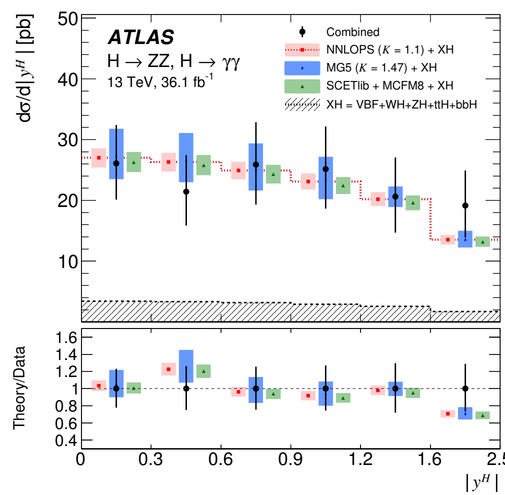


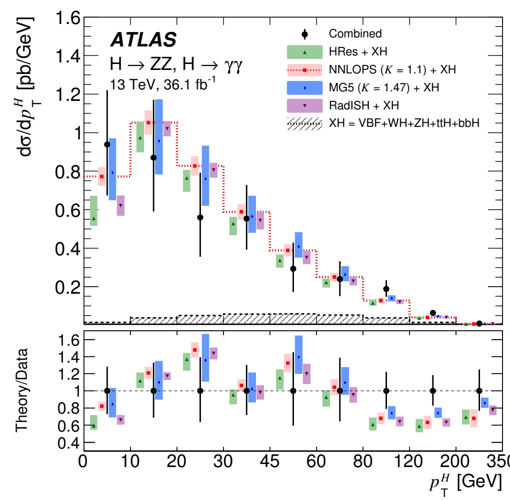




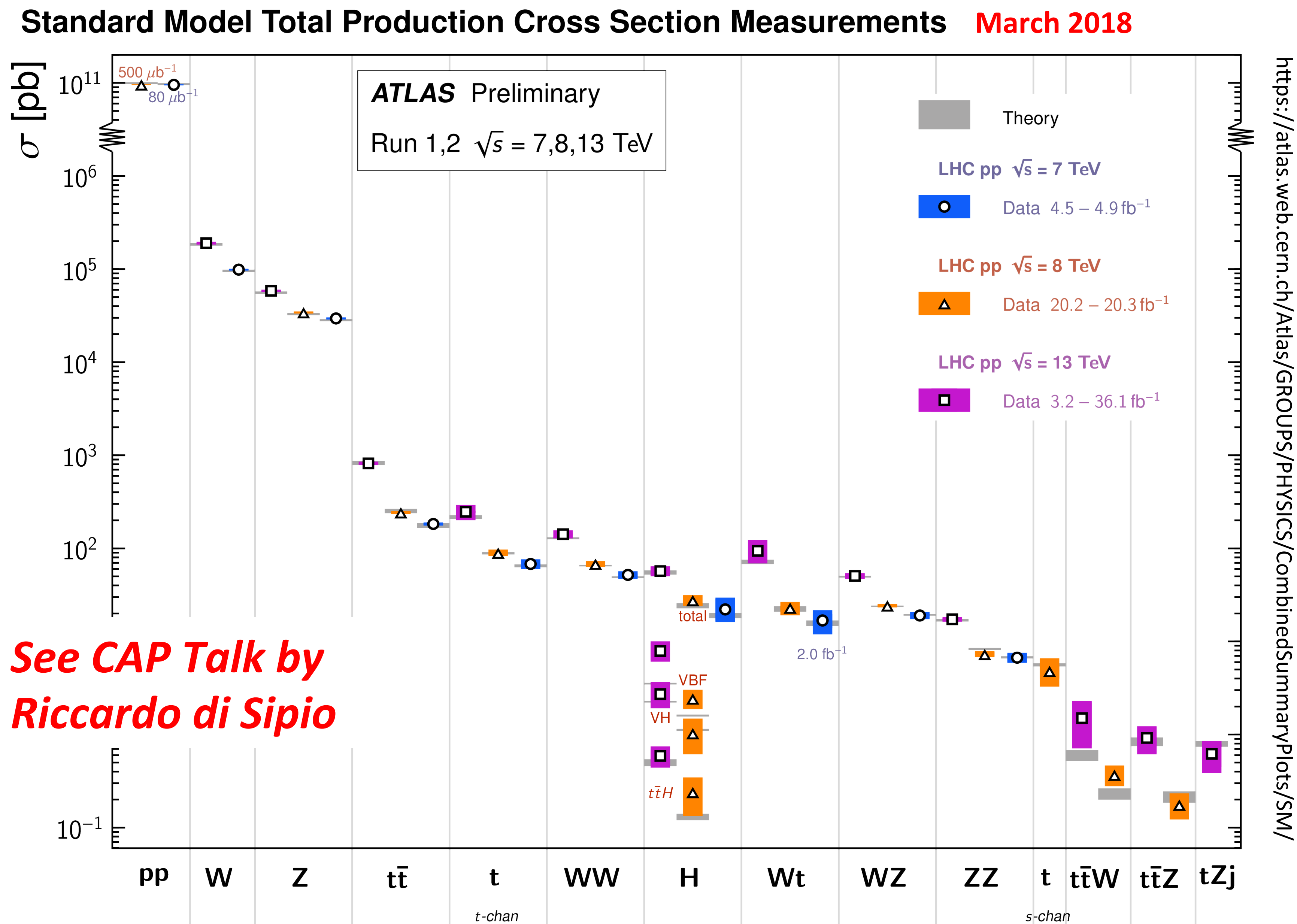
1805.10197







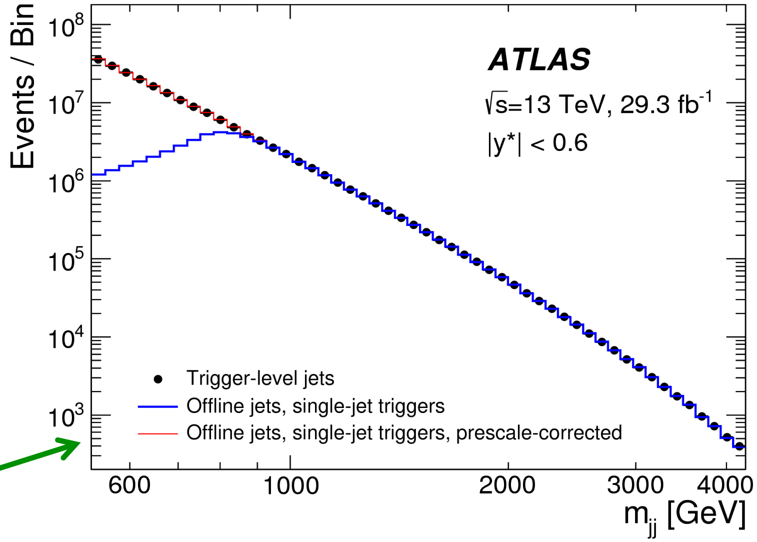
Other Standard Model Cross-sections



See CAP Talk by Riccardo di Sipio

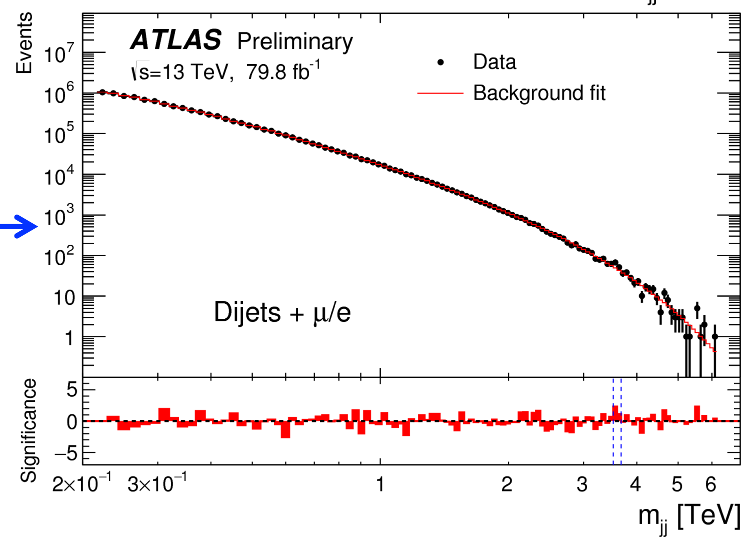
Searches for Dijet Resonances

- **Standard searches for dijet resonance typically one of the first results when running at new energy. Was an early Run-2 result:**
  - Early studies at a new energy typically focus on the high-mass region
    - Standard analysis good for this but has poor sensitivity below about 1 TeV due to trigger thresholds
  - Low mass region is also interesting!
    See http://cerncourier.com/cws/article/cern/71527



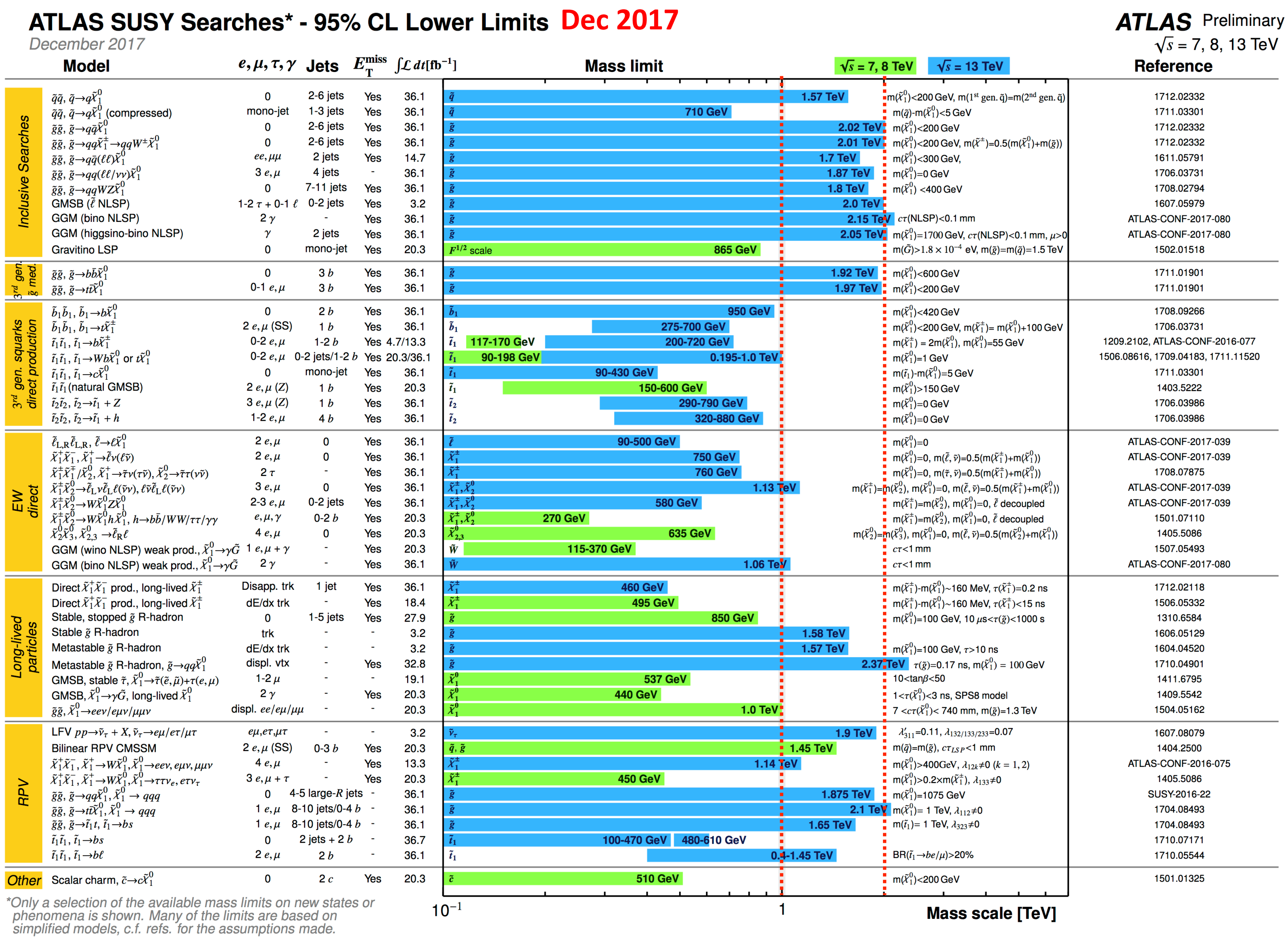
- **Can access this using**
  - trigger level jets [1804.03496]
  - dijet + ISR event [1801.08769] (not shown)
  - dijets + lepton events [ATLAS-CONF-2018-015]

    New preliminary result using 80 fb^{-1}



No significant deviations observed

SUSY Search Summary



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/SUSY/

See CAP Talk by Kate Pachal

13 TeV dataset

Exotics Search Summary

ATLAS Exotics Searches* - 95% CL Upper Exclusion Limits July 2017

Status: July 2017

ATLAS Preliminary

$\int \mathcal{L}\,dt = (3.2 - 37.0)\ \text{fb}^{-1}$ $\sqrt{s}$ = 8, 13 TeV

	Model	ℓ, γ	Jets†	E_T^{miss}	$\int \mathcal{L}\,dt[\text{fb}^{-1}]$	Limit		Reference
Extra dimensions	ADD $G_{KK} + g/q$	0 e, μ	1 – 4 j	Yes	36.1	M_D 7.75 TeV	$n = 2$	ATLAS-CONF-2017-060
	ADD non-resonant $\gamma\gamma$	2 γ	–	–	36.7	M_S 8.6 TeV	$n = 3$ HLZ NLO	CERN-EP-2017-132
	ADD QBH	–	2 j	–	37.0	M_{th} 8.9 TeV	$n = 6$	1703.09217
	ADD BH high $\sum p_T$	≥ 1 e, μ	≥ 2 j	–	3.2	M_{th} 8.2 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1606.02265
	ADD BH multijet	–	≥ 3 j	–	3.6	M_{th} 9.55 TeV	$n = 6$, $M_D = 3$ TeV, rot BH	1512.02586
	RS1 $G_{KK} \to \gamma\gamma$	2 γ	–	–	36.7	G_{KK} mass 4.1 TeV	$k/\overline{M}_{Pl} = 0.1$	CERN-EP-2017-132
	Bulk RS $G_{KK} \to WW \to qq\ell\nu$	1 e, μ	1 J	Yes	36.1	G_{KK} mass 1.75 TeV	$k/\overline{M}_{Pl} = 1.0$	ATLAS-CONF-2017-051
	2UED / RPP	1 e, μ	≥ 2 b, ≥ 3 j	Yes	13.2	KK mass 1.6 TeV	Tier (1,1), $\mathcal{B}(A^{(1,1)} \to tt) = 1$	ATLAS-CONF-2016-104
Gauge bosons	SSM $Z' \to \ell\ell$	2 e, μ	–	–	36.1	Z' mass 4.5 TeV		ATLAS-CONF-2017-027
	SSM $Z' \to \tau\tau$	2 τ	–	–	36.1	Z' mass 2.4 TeV		ATLAS-CONF-2017-050
	Leptophobic $Z' \to bb$	–	2 b	–	3.2	Z' mass 1.5 TeV		1603.08791
	Leptophobic $Z' \to tt$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	3.2	Z' mass 2.0 TeV	$\Gamma/m = 3\%$	ATLAS-CONF-2016-014
	SSM $W' \to \ell\nu$	1 e, μ	–	Yes	36.1	W' mass 5.1 TeV		1706.04786
	HVT $V' \to WW \to qqqq$ model B	0 e, μ	2 J	–	36.7	V' mass 3.5 TeV	$g_V = 3$	CERN-EP-2017-147
	HVT $V' \to WH/ZH$ model B	multi-channel			36.1	V' mass 2.93 TeV	$g_V = 3$	ATLAS-CONF-2017-055
	LRSM $W'_R \to tb$	1 e, μ	2 b, 0-1 j	Yes	20.3	W' mass 1.92 TeV		1410.4103
	LRSM $W'_R \to tb$	0 e, μ	≥ 1 b, 1 J	–	20.3	W' mass 1.76 TeV		1408.0886
CI	CI $qqqq$	–	2 j	–	37.0	Λ 21.8 TeV	η_{LL}^-	1703.09217
	CI $\ell\ell qq$	2 e, μ	–	–	36.1	Λ 40.1 TeV	η_{LL}^-	ATLAS-CONF-2017-027
	CI $uutt$	2(SS)/≥3 e,μ	≥1 b, ≥1 j	Yes	20.3	Λ 4.9 TeV	$\lvert C_{RR}\rvert = 1$	1504.04605
DM	Axial-vector mediator (Dirac DM)	0 e, μ	1 – 4 j	Yes	36.1	m_{med} 1.5 TeV	g_q=0.25, g_χ=1.0, $m(\chi)$ < 400 GeV	ATLAS-CONF-2017-060
	Vector mediator (Dirac DM)	0 e, μ, 1 γ	≤ 1 j	Yes	36.1	m_{med} 1.2 TeV	g_q=0.25, g_χ=1.0, $m(\chi)$ < 480 GeV	1704.03848
	$VV\chi\chi$ EFT (Dirac DM)	0 e, μ	1 J, ≤ 1 j	Yes	3.2	M_* 700 GeV	$m(\chi)$ < 150 GeV	1608.02372
LQ	Scalar LQ 1st gen	2 e	≥ 2 j	–	3.2	LQ mass 1.1 TeV	$\beta = 1$	1605.06035
	Scalar LQ 2nd gen	2 μ	≥ 2 j	–	3.2	LQ mass 1.05 TeV	$\beta = 1$	1605.06035
	Scalar LQ 3rd gen	1 e, μ	≥1 b, ≥3 j	Yes	20.3	LQ mass 640 GeV	$\beta = 0$	1508.04735
Heavy quarks	VLQ $TT \to Ht + X$	0 or 1 e, μ	≥ 2 b, ≥ 3 j	Yes	13.2	T mass 1.2 TeV	$\mathcal{B}(T \to Ht) = 1$	ATLAS-CONF-2016-104
	VLQ $TT \to Zt + X$	1 e, μ	≥ 1 b, ≥ 3 j	Yes	36.1	T mass 1.16 TeV	$\mathcal{B}(T \to Zt) = 1$	1705.10751
	VLQ $TT \to Wb + X$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	T mass 1.35 TeV	$\mathcal{B}(T \to Wb) = 1$	CERN-EP-2017-094
	VLQ $BB \to Hb + X$	1 e, μ	≥ 2 b, ≥ 3 j	Yes	20.3	B mass 700 GeV	$\mathcal{B}(B \to Hb) = 1$	1505.04306
	VLQ $BB \to Zb + X$	2/≥3 e, μ	≥2/≥1 b	–	20.3	B mass 790 GeV	$\mathcal{B}(B \to Zb) = 1$	1409.5500
	VLQ $BB \to Wt + X$	1 e, μ	≥ 1 b, ≥ 1J/2j	Yes	36.1	B mass 1.25 TeV	$\mathcal{B}(B \to Wt) = 1$	CERN-EP-2017-094
	VLQ $QQ \to WqWq$	1 e, μ	≥ 4 j	Yes	20.3	Q mass 690 GeV		1509.04261
Excited fermions	Excited quark $q^* \to qg$	–	2 j	–	37.0	q^* mass 6.0 TeV	only u^* and d^*, $\Lambda = m(q^*)$	1703.09127
	Excited quark $q^* \to q\gamma$	1 γ	1 j	–	36.7	q^* mass 5.3 TeV	only u^* and d^*, $\Lambda = m(q^*)$	CERN-EP-2017-148
	Excited quark $b^* \to bg$	–	1 b, 1 j	–	13.3	b^* mass 2.3 TeV		ATLAS-CONF-2016-060
	Excited quark $b^* \to Wt$	1 or 2 e, μ	1 b, 2-0 j	Yes	20.3	b^* mass 1.5 TeV	$f_g = f_L = f_R = 1$	1510.02664
	Excited lepton ℓ^*	3 e, μ	–	–	20.3	ℓ^* mass 3.0 TeV	Λ = 3.0 TeV	1411.2921
	Excited lepton ν^*	3 e, μ, τ	–	–	20.3	ν^* mass 1.6 TeV	Λ = 1.6 TeV	1411.2921
Other	LRSM Majorana ν	2 e, μ	2 j	–	20.3	N^0 mass 2.0 TeV	$m(W_R) = 2.4$ TeV, no mixing	1506.06020
	Higgs triplet $H^{\pm\pm} \to \ell\ell$	2,3,4 e, μ (SS)	–	–	36.1	$H^{\pm\pm}$ mass 870 GeV	DY production	ATLAS-CONF-2017-053
	Higgs triplet $H^{\pm\pm} \to \ell\tau$	3 e, μ, τ	–	–	20.3	$H^{\pm\pm}$ mass 400 GeV	DY production, $\mathcal{B}(H_L^{\pm\pm} \to \ell\tau) = 1$	1411.2921
	Monotop (non-res prod)	1 e, μ	1 b	Yes	20.3	spin-1 invisible particle mass 657 GeV	$a_{\text{non-res}} = 0.2$	1410.5404
	Multi-charged particles	–	–	–	20.3	multi-charged particle mass 785 GeV	DY production, $\lvert q\rvert = 5e$	1504.04188
	Magnetic monopoles	–	–	–	7.0	monopole mass 1.34 TeV	DY production, $\lvert g\rvert = 1g_D$, spin 1/2	1509.08059

$\sqrt{s}$ = 8 TeV $\sqrt{s}$ = 13 TeV

10^{-1} 1   10   Mass scale [TeV]

*Only a selection of the available mass limits on new states or phenomena is shown.

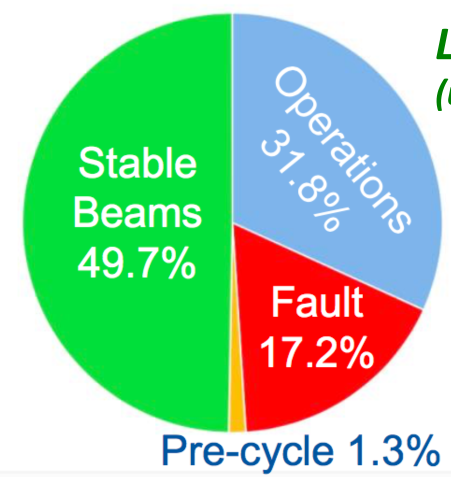
†Small-radius (large-radius) jets are denoted by the letter j (J).

https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/CombinedSummaryPlots/EXOTICS/

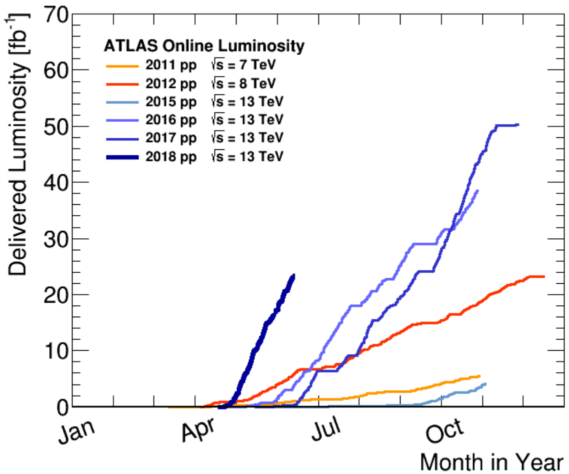
See CAP Talk by Kate Pachal

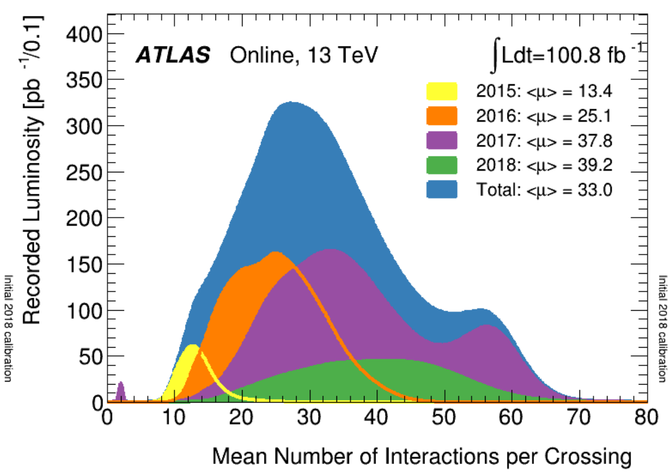
LHC / ATLAS Startup 2018

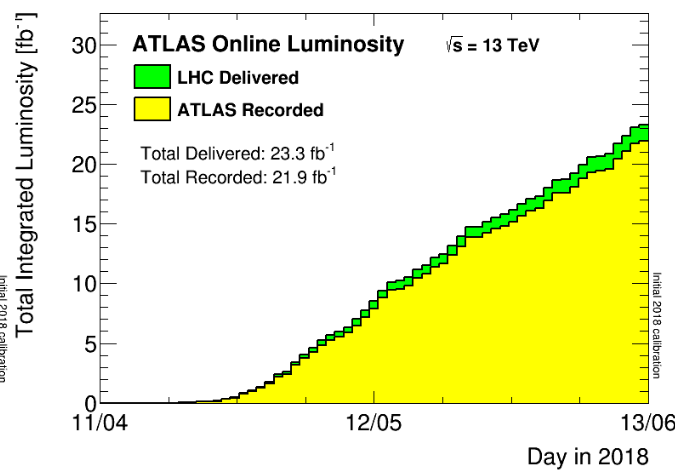
- **First 2018 stable beams collisions April 17 (was May 23 in 2017)**
- **Problems in cell 16L2 are back:**
  - Less severe; different mitigation strategy
    - Brief run with 900 bunches, then back to 2556
- **Otherwise relatively smooth operation**
- **Recently surpassed 100 fb^{-1} at 13 TeV**
  - 21.9 fb^{-1} recorded so far in 2018 (June 12)
- **Excellent machine availability (as in 2017)**



LHC 2018
(up to May 28)

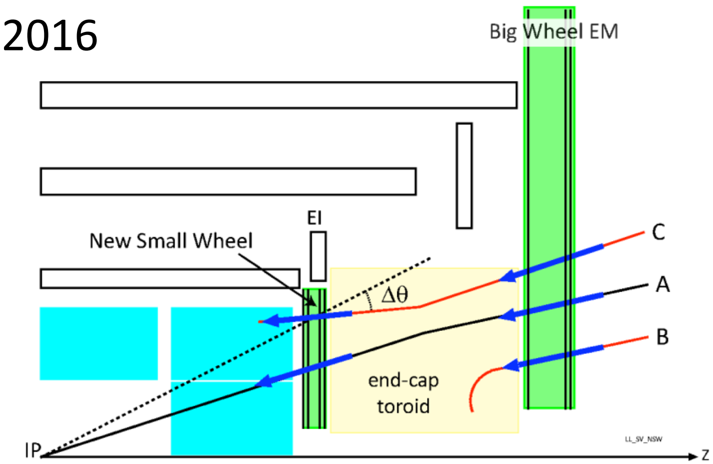


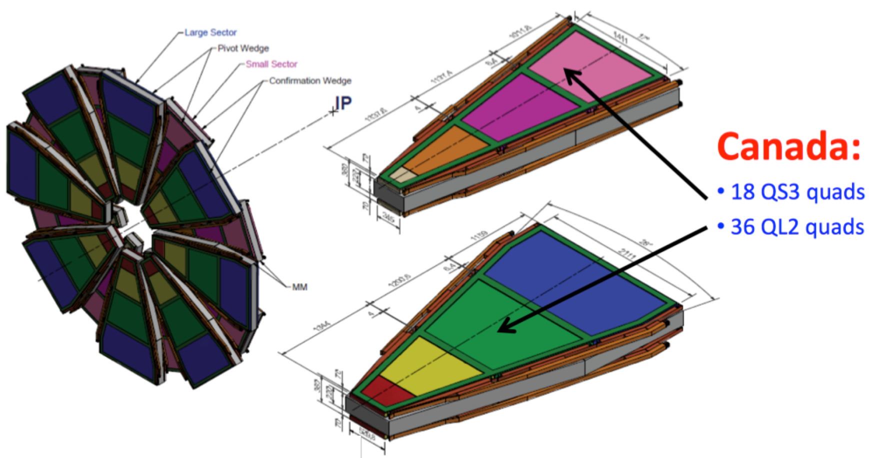




Phase-1 Upgrades: Muon New Small Wheel

- **NSW key component of muon trigger for Run-3 (fake rejection with pointing)**
- **sTGC construction / testing infrastructure at TRIUMF, Carleton and McGill**
  - Module-0 sTGC completed by Canadian group in May 2016
  - Production Readiness Review (PRR) passed in June 2016
- **Leading coordination roles in NSW project:**
  - Overall project management, schedule, finances
  - Leadership of sTGC project
  - Wedge assembly at CERN
  - Software / simulation
  - Electronics / software for cosmic-ray test station
  - Production test pulser board for sTGCs
- **Production delays due to component procurement:**
  - Also delays for other NSW sub-systems
  - First production module now being tested at McGill





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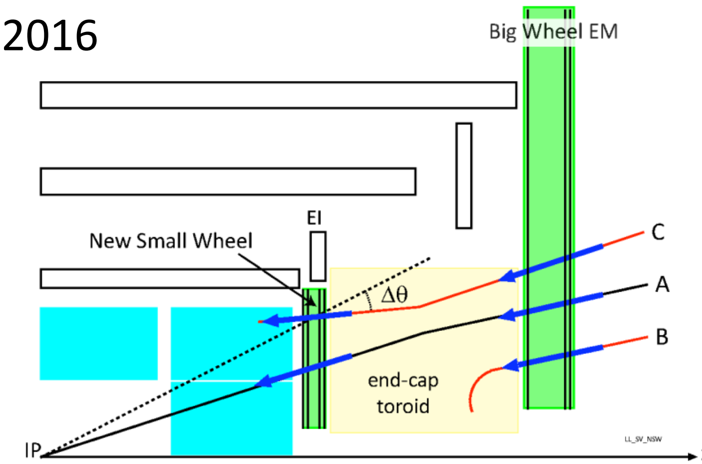
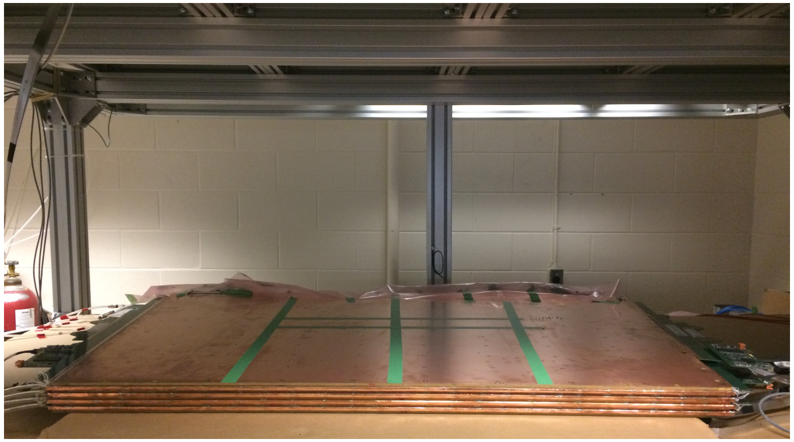


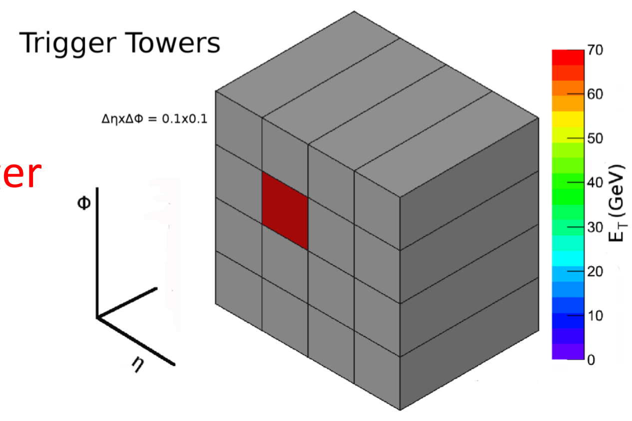
See CAP talk by T. Kwan



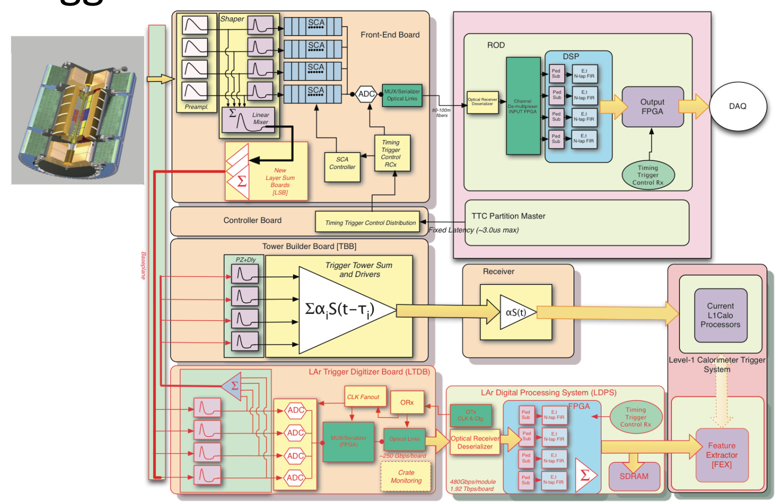
Phase-1 Upgrades: LAr Calorimeter Electronics

- **Another key component of ATLAS trigger strategy for Run-3**
- **Improve granularity of information supplied to the L1 trigger**
  - Provide additional background suppression at trigger level

Current trigger granularity



(a)



- **Implementation requires new Front-End Crate baseplanes**
- **For the HEC, these are being developed and produced by Victoria / TRIUMF**
  - Design approved in 2015: pre-production board have been produced and tested
  - Production Readiness Review completed in Feb 2018
  - PCB manufacturing complete; boards now being connectorized in industry
  - Expected at TRIUMF in July; testing to follow at UVic

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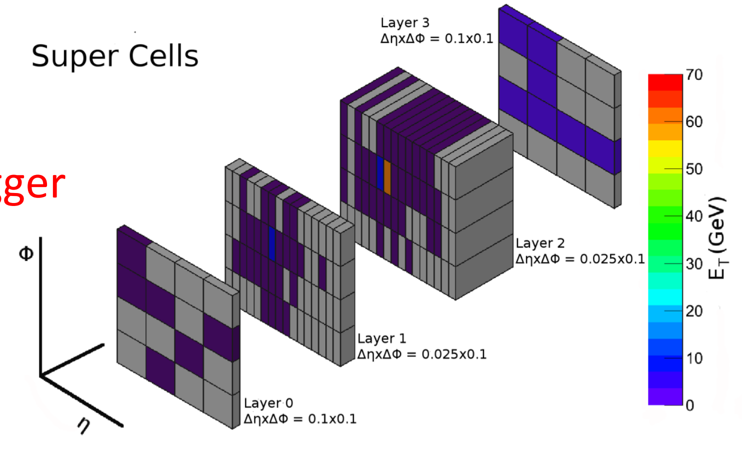
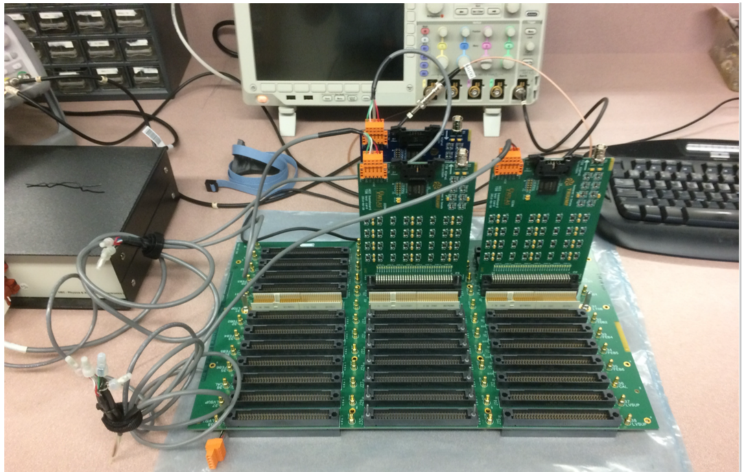
Phase-1 trigger granularity



(b)



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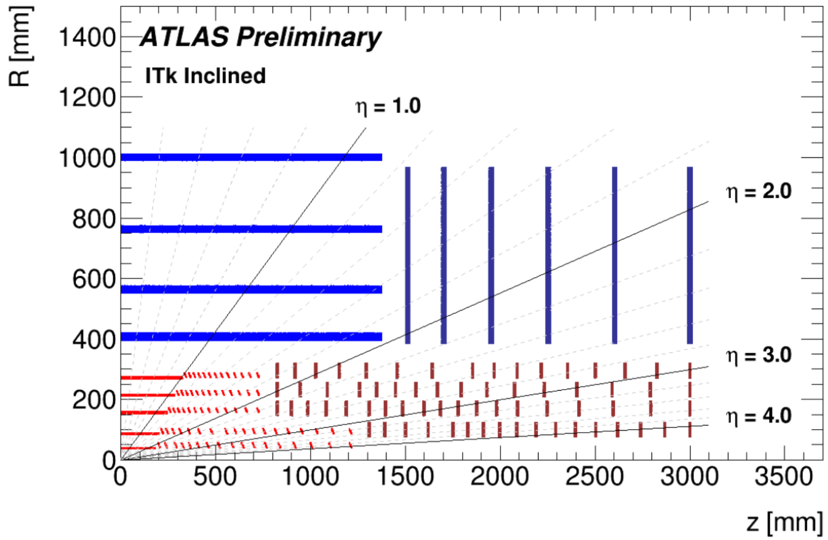
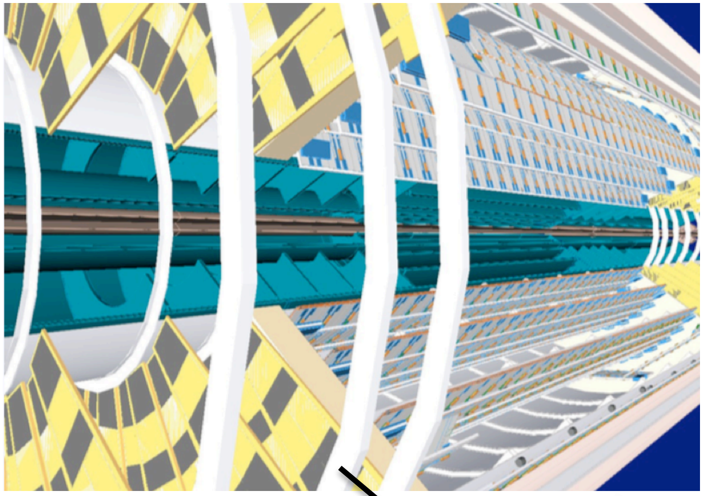
Full Phase-1 LAr upgrade project progressing well

ATLAS at the High Luminosity LHC

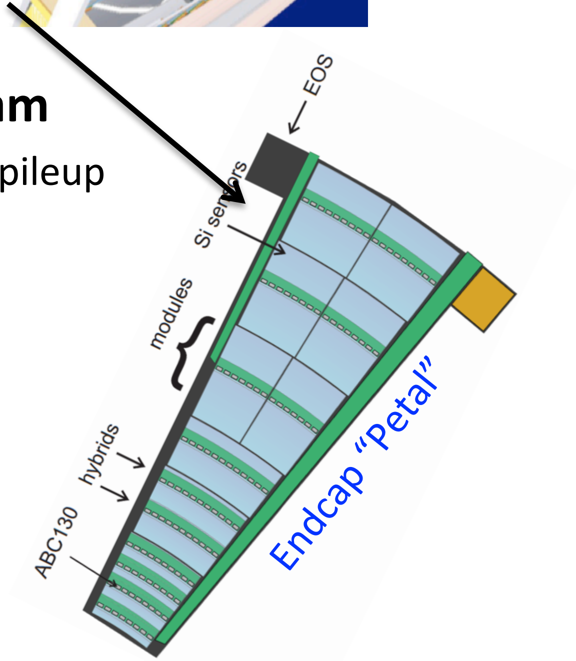
- **Proposed instantaneous luminosity of 7.5×10^{34} cm^{-2}s^{-1} (μ≈200)**
  - Needed for the desired (×10) increase in integrated luminosity
  - Rate and accumulated dose causes problems for some detector subsystems
  - Need for pileup suppression becomes crucial issue for detector upgrades
- **Proposed L0/L1 trigger scheme with rates of 1MHz/400KHz is incompatible with both tracker and calorimeter readout electronics:**
  - **Calorimeter front- and back-end electronics must be entirely replaced**
- **Radiation dose and occupancy also an issue for the tracker**
  - **This will be entirely replaced by a new all-silicon tracker, the ITk**
    - Pixels at low radius, strips at higher radius.
      - Coverage out to |η| = 4.0 (from 2.5 for current inner tracker)
    - 160 m^2 of silicon. Almost half the cost / effort of Phase-II upgrades
- **Anticipate some coverage improvements for Muon system**
- **ATLAS investigating dedicated (Si) timing detector in the forward region**
- **Canadian participation funded by CFI in IF 2017 competition**
  - We have multiple technical leadership & management roles in both projects

Phase-II Tracker Upgrade (ITk)





- **Excellent tracking needed for the HL-LHC physics program**
  - Need precision vertexing to identify the primary vertex from high pileup
- **Canadian group contributing to construction of the Endcap Strips detector:**
  - about 18k Si strip modules needed (~7000 in endcap):
  - plan for 1500 in Canada (2 sites: Vancouver, Toronto)
  - Additional planned contributions:
    - Industrialize production of "hybrid boards"
    - Module placement on support structure for Endcap "petals"
    - Readout electronics ASIC wafer probing and dicing
    - Simulation infrastructure



See CAP talks by F. Guescini and J. Bottte

Phase-II LAr Calorimeter Upgrade Work

- **Proposed forward calorimeter replacement decided against in Sept. 2016**
  - Risk (damage to other endcap calorimeter subsystems) vs. reward (improved performance) study concluded that the benefits are not work the risks
- **Canadian groups integrating into Phase-II electronics effort:**
  - Naturally follows our Phase-I work and historical contributions to ATLAS
  - Focus on front-end electronics for the HEC
    - HEC was built in part in Canada
    - Different from other LAr subsystems, due to cold preamplifiers in the cryostat
      - Exploit particular Canadian expertise in the HEC readout
  - Also taking leadership role in development of FPGA-based back-end (off-detector) system
    - Data handling
    - FPGA-based filtering algorithms used for energy reconstruction
- **Canadians occupy a significant fraction coordination roles:**
  - Simulation group, Front-End group, Resources

Summary

- **LHC/ATLAS operations were excellent in 2017**
  - Smooth startup in 2018. $\mathcal{L}_{int}$ slope ≈ that achieved towards end of 2017
  - Earlier start to 2018 run year; targeting integrated luminosity of 60 fb^{-1}
- **Canadian group successfully engaged in all aspects of ATLAS**
  - Important and visible roles in the Collaboration
  - Physics output (analysis, review, physics group & sub-group convenors, etc.)
  - Detector operations (run coordinators for multiple subsystems), computing
  - Strong participation in detector upgrade activities **See CAP talk by N. Hessey**
    - Phase-1: LAr trigger electronics, sTGCs for NSW
    - Phase-2: LAr readout electronics, ITk
    - Including leadership roles in both Phase-1 and Phase-2 projects
- **Also pursuing a contribution to the HL-LHC accelerator upgrade**
  - With the help of IPP Director and the support of TRIUMF
  - Meeting between CERN DG and Science Minister Duncan in Nov 2017
  - CERN visit by Canada's Chief Science Advisor (M. Nemer) in May 2018
  - Decision on this is expected soon

ATLAS Talks at the 2018 CAP Congress

11 ATLAS talks at 2018 CAP Congress

Invited

- Searches for New Physics at ATLAS, *K. Pachal*
- Standard Model and Higgs results from ATLAS, *R. di Sipio*
- The ATLAS Upgrade for the High-Luminosity LHC, *N. Hessey*

Contributed (upgrade hardware)

- ATLAS ITk activities at SFU, TRIUMF and UBC
- Performance of Canadian-made muon chambers for the ATLAS experiment Phase-1 upgrade
- Developing ITk Front-end Silicon-strips Readout ASICs Testing Capability

Contributed (physics)

- Measurement of the Drell–Yan triple-differential cross section in pp collisions at $\sqrt{s}$ = 8 TeV
- High mass Diboson Resonances with the ATLAS Detector
- Search for dark matter candidates produced in Z(ll) + ETmiss events in 13 TeV proton-proton collisions with the ATLAS detector at the Large Hadron Collider
- Search for new dark sector particles in Higgs boson decays with the ATLAS detector at the LHC
- Measurement of Z bosons produced in association with jets via vector boson fusion at 13 TeV with the ATLAS detector

Backup

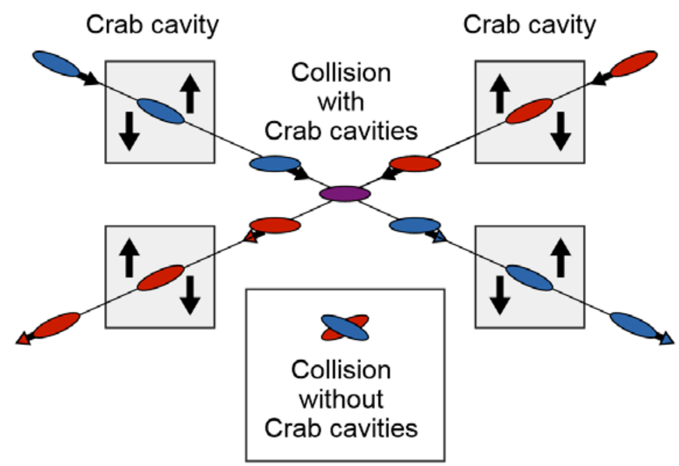
LHC Schedule 2018

ATLAS Canada Operations & Upgrade Funding

- **Operations: currently in first year of new three-year NSERC project grant**
  - 2018—2021 (proposal submitted in fall 2017)
- **Phase-1 Upgrades**
  - LAr, NSW projects currently under construction, funded by CFI IF 2015 award
  - Significant initial R&D support from NSERC in 2013, 2014
- **Phase-2 Upgrades**
  - NSERC RTI awards in 2016 and 2017 for R&D phase
  - Construction funding from CFI in IF 2017 competition:
    - LAr Electronics, ITk, Upgrade Common Fund
    - Award Finalization process underway (condition lifted in mid-May)
- **Computing**:
  - Tier-1 hardware refresh also funded in IF 2017 competition (BCKDF matching)
  - CyberInfrastructure award for personnel (including CERN-based)
- **Canadian contributions to LHC → HL-LHC upgrade still being pursued**
  - CERN has requested that we contribute to the HL-LHC accelerator upgrade
    - We made significant contributions to the original LHC construction

Proposed Contribution to LHC Accelerator Upgrade

- **The heart of the HL-LHC upgrade are the "crab cavities" that rotate the proton bunches before collision, to maximize the overlap**
- **Canada has been asked to contribute half of the "cryomodules" that house these devices:**
  - builds on existing expertise at TRIUMF
  - Canadian industry would be an essential partner



- **Cost is $12M: $10M in new funds from the federal government + $2M from TRIUMF**
- **Discussed in meeting of CERN DG and Science Minister Duncan in Nov 2017**
- **Crab-cavity test facility part of CERN visit by Canadian Chief Science Advisor in May.**
- **Decision expected soon**